P-FEM FOR FLUID-STRUCTURE INTERACTION PROBLEMS

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Aircraft structural components in flight as well as blood flow in myocardial arteries involve fluid and structure interactions. Simulation of such phenomena requires the solution of highly non-linear hyperbolic equations for the flow and nonlinear elliptic equations for the structure (which usually has a complex geometry), and these have to be coupled.

Past efforts require simplifying assumptions to be made either in the fluid or the structural solver. On the part of the fluid solvers, assumptions like non-viscous Euler or different turbulence models are used to simplify the fluid computation. On the part of the structure, linear elasticity is usually assumed, and thin solid structures are modelled with combinations of beam, plate and shell elements, each of which are formulated upon certain assumptions. These simplifications have led to advancement in the area of fluid/structure interaction, however the assumptions under which these simplifications are made lead to an idealization error – error which needs to be quantified.

In an effort to minimize both idealization and discretization errors, the use of a parallel spectral/hp element fluid solver (enabling a good and fast resolution of the flow field), linked to a hp-FEM structural solver (enabling a realistic representation of thin solid structures undergoing large displacements and strains), is proposed as a natural choice for simulating such situations as wing structures in flight. To this end, we present results for the coupling of the fluid solver $\mathcal{N}\varepsilon\kappa\mathcal{T}\alpha r$ with the solid solver StressCheck[2]. A realistic approach, which may represent both geometrical as well as material nonlinearities in the structure, is based on a two-way coupling of the fluid solver $\mathcal{N}\varepsilon\kappa\mathcal{T}\alpha r$ with StressCheck.

The two-way coupling strategy is under investigation, and we explore aspects of modeling error by performing a geometrical non-linear analysis of a typical wing in flow which will be compared to the wing as if it behaves linearly elastic. This will provide a quantitative measure as to the role of large deformations on the validity of results obtained under the assumption of linear elasticity (which is usually used in such simulations). We will also present some recent results of a plate in a flow, where the plate is represented by the non-linear, dynamic, von-Kármán model and the flow is represented using the full Navier-Stokes equations.

From the algorithmic point of view, several staggered algorithms are investigated, and the most efficient and accurate will be adopted and reported. We will report on the efficiency of a combined hp-fluid/ph-structure interaction code, and address the methods for coupling two software products running and interacting on two different platforms and operating systems. The difficulties associated with different meshes for the fluid and structural domains will also be addressed.